Academic Language and the Challenge of Reading for Learning About Science

Catherine E. Snow

Science **328**, 450 (2010);
DOI: 10.1126/science.1182597

their learners' struggles to come to terms with unfamiliar language, discourse patterns, and the often formidable conventions of science (*27*).

References

1. P. Fensham, *Science Education Policy-Making: Eleven Emerging Issues* [Commissioned by United Nations Educational, Scientific, and Cultural Organization (UNESCO) Section for Science, Technical, and Vocational Education; Paris; 2008].
2. S. P. Norris, L. M. Phillips, *Sci. Educ.* **87**, 224 (2003).
3. L. D. Yore, G. L. Bisanz, B. M. Hand, *Int. J. Sci. Educ.* **25**, 689 (2003).
4. B. M. Hand, V. Prain, L. D. Yore, in *Writing as a Learning Tool: Integrating Theory and Practice*, P. Tynjälä, L. Mason, K. Lonka, Eds. (Kluwer, Dordrecht, Netherlands, 2001), pp. 105–129.
5. L. D. Yore, D. F. Treagust, *Int. J. Sci. Educ.* **28**, 291 (2006).
6. H. Alidou *et al.*, *Optimizing Learning and Education in Africa—the Language Factor: A Stock Taking Research on Mother Tongue and Bilingual Education in Sub-Saharan Africa* (UNESCO Institute for Education, Libreville, Gabon, 2006).
7. N. R. Romance, M. R. Vitale, *J. Res. Sci. Teach.* **29**, 545 (1992).
8. N. R. Romance, M. R. Vitale, in *Linking Science and Literacy in the K–8 Classroom*, R. Douglas, M. P. Klentschy, K. Worth, W. Binder, Eds. [National Science Teachers Association (NSTA) Press, Arlington, VA, 2006], pp. 391–405.
9. N. R. Romance, M. R. Vitale, *NSF/IERI Science IDEAS Project* (Technical Report 0228353-0014, Florida Atlantic University, Boca Raton, FL, 2008).
10. G. Cervetti, P. Pearson, M. Bravo, J. Barber, in *Linking Science and Literacy in the K–8 Classroom*, R. Douglas, M. Klentschy, K. Worth, Eds. (NSTA Press, Arlington, VA, 2006), pp. 221–224.
11. O. M. Amaral, L. Garrison, M. Klentschy, *Biling. Res. J.* **26**, 213 (2002).
12. M. Revak, P. Kuerbis, paper presented at the International Meeting of the Association for Science Teacher Education, St. Louis, MO, 9 to 12 January 2008.
13. B. Hand, Ed., *Science Inquiry, Argument and Language: A Case for the Science Writing Heuristic* (Sense Publishers, Rotterdam, Netherlands, 2007).
14. M. Gunel, B. Hand, V. Prain, *Int. J. Sci. Math. Educ.* **5**, 615 (2007).
15. M. A. McDermott, B. Hand, paper presented at the International Meeting of the Association for Science Teacher Education, St. Louis, MO, 9 to 12 January 2008.
16. M. Setati, J. Adler, Y. Reed, A. Bapoo, *Lang. Educ.* **16**, 128 (2002).
17. Department of Education, *National Education Quality Initiative and Education, Science and Skills Development Grade 6 Systemic Evaluation* (Department of Education, Pretoria, South Africa, 2005).
18. V. Rodseth, *Bilingualism and Multilingualism in Education* (Centre for Continuing Development, Johannesburg, 1995).
19. C. Ballenger, *Lang. Educ.* **11**, 1 (1997).
20. P. Webb, D. Treagust, *Res. Sci. Educ.* **36**, 381 (2006).
21. M. G. Villanueva, P. Webb, *Afr. J. Res. Math. Sci. Technol. Educ.* **12**, 5 (2008).
22. P. Webb, Y. Williams, L. Meiring, *Afr. J. Res. Math. Sci. Technol. Educ.* **12**, 4 (2008).
23. P. Webb, *Int. J. Environ. Sci. Educ.* **4**, 313 (2009).
24. C. R. Nesbit, T. Y. Hargrove, L. Harrelson, B. Maxey, *Implementing Science Notebooks in the Primary Grades: Science Activities Journal* (Heldref, Washington, DC, 2003).
25. D. August, T. Shanahan, Eds., *Developing Literacy in Second-Language Learners: Report of the National Literacy Panel on Language-Minority Children and Youth* (Lawrence Erlbaum, Mahwah, NJ, 2006).
26. J. Cummins, *Appl. Linguist.* **2**, 132 (1981).
27. D. Hodson, *Teaching and Learning About Science: Language, Theories, Methods, History, Traditions and Values* (Sense Publishers, Rotterdam, Netherlands, 2009).

10.1126/science.1182596

PERSPECTIVE

Academic Language and the Challenge of Reading for Learning About Science

Catherine E. Snow

A major challenge to students learning science is the academic language in which science is written. Academic language is designed to be concise, precise, and authoritative. To achieve these goals, it uses sophisticated words and complex grammatical constructions that can disrupt reading comprehension and block learning. Students need help in learning academic vocabulary and how to process academic language if they are to become independent learners of science.

Literacy scholars and secondary teachers alike are puzzled by the frequency with which students who read words accurately and fluently have trouble comprehending text (*1*, *2*). Such students have mastered what was traditionally considered the major obstacle to reading success: the depth and complexity of the English spelling system. But many middle- and high-school students are less able to convert their word-reading skills into comprehension when confronted with texts in science (or math or social studies) than they are when confronted with texts of fiction or discursive essays. The greater difficulty of science, math, and social studies texts than of texts encountered in English language arts (mostly narratives) suggests that the comprehension of "academic language" may be one source of the challenge. So what is academic language?

Harvard Graduate School of Education, Harvard University, Cambridge, MA.

Academic language is one of the terms [others include language of education (*3*), language of schooling (*4*), scientific language (*5*), and academic English (*6*, *7*)] used to refer to the form of language expected in contexts such as the exposition of topics in the school curriculum, making arguments, defending propositions, and synthesizing information. There is no exact boundary when defining academic language; it falls toward one end of a continuum (defined by formality of tone, complexity of content, and degree of impersonality of stance), with informal, casual, conversational language at the other extreme. There is also no single academic language, just as there is no single variety of educated American English. Academic language features vary as a function of discipline, topic, and mode (written versus oral, for example), but there are certain common characteristics that distinguish highly academic from less academic or more conversational language and that make academic language—even well-written, carefully constructed, and professionally edited academic language—difficult to comprehend and even harder to produce (*8*).

Among the most commonly noted features of academic language are conciseness, achieved by avoiding redundancy; using a high density of information-bearing words, ensuring precision of expression; and relying on grammatical processes to compress complex ideas into few words (*8*, *9*). Less academic language, on the other hand, such as that used in e-mails, resembles oral language forms more closely: Most sentences begin with pronouns or animate subjects; verbs refer to actions rather than relations; and long sentences are characterized by sequencing of information rather than embeddings. The two excerpts in Fig. 1, both about torque (a topic included in many state standards for 7th-grade science), display the difference between a nonacademic text (from the Web site www.lowrider.com) and an academic text (from the Web site www.tutorvista.com).

A striking difference between more informal and more academic language exemplified in the Lowrider/TutorVista text comparison is the greater presence of expressive, involved, interpersonal stance markers in the first Lowrider posting ("…guys get caught up…," "I frequently get asked…," "Most of us…,") and in the response

From http://www.lowrider.com/forums/10-Under-the-Hood/topics/183-HP-vs-torque/posts (spelling as in the original posting)

Often times guys get caught up in the hype of having a big HP motor in their lolo. I frequently get asked whats the best way to get big numbers out of their small block. The answer is not HP, but torque. "You sell HP, you feel torque" as the old saying goes. Most of us are running 155/80/13 tires on our lolo's. Even if you had big HP numbers, you will *never* get that power to the ground, at least off the line. I have a 64 Impala SS 409, that i built the motor in. While it is a completely restored original (I drive it rolling on 14" 72 spoke cross laced Zeniths), the motor internals are not. It now displaces 420 CI, with forged pistons and blalanced rotating assembly. The intake, carb and exhaust had to remain OEM for originality's sake, and that greatly reduces the motors potential. Anyway, even with the original 2 speed powerglide, it spins those tires with alarming ease, up to 50 miles per hour!

In my 62, I built a nice 383 out of an 86 Corvette. I built it for good bottom end pull, since it is a lowrider with 8 batteries. And since it rides on the obligitory 13's, torque is what that car needs. It pulls like an ox right from idle, all the way up to its modest 5500 redline. But I never take it that high, as all the best power is from 1100 to 2700 RPM.

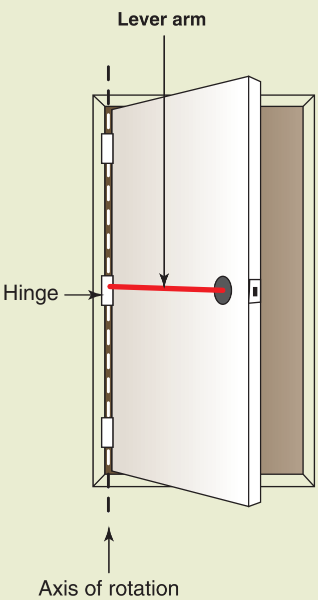
So when considering an engine upgrade, look for modifications that improve torque. That is what your lolo needs!

Posted by Jason Dave, Sept 2009

Jason you are right on bro. I have always found an increase in torque placement has not only provided better top end performance but also improved gas mileage in this expensive gas times.

Posted by Gabriel Salazar, Nov 2009

From http://www.tutorvista.com/content/physics/physics-iii/rigid-body/torque.php



Torque is the product of the magnitude of the force and the lever arm of the force.
What is the significance of this concept in our everyday life?

Dependence of torque on lever arm
To increase the turning effect of force, it is not necessary to increase the magnitude of the force itself. We may increase the turning effect of the force by changing the point of application of force and by changing the direction of force.

Let us take the case of a heavy door. If a force is applied at a point, which is close to the hinges of the door, we may find it quite difficult to open or close the door. However, if the same force is applied at a point, which is at the maximum distance from hinges, we can easily close or open the door. The task is made easier if the force is applied at right angles to the plane of the door.

When we apply the force the door turns on its hinges. Thus a turning effect is produced when we try to open the door. Have you ever tried to do so by applying the force near the hinge? In the first case, we are able to open the door with ease. In the second case, we have to apply much more force to cause the same turning effect. What is the reason?

The turning effect produced by a force on a rigid body about a point, pivot or fulcrum is called the moment of a force or torque. It is measured by the product of the force and the perpendicular distance of the pivot from the line of action of the force.

Moment of a force = Force x Perpendicular distance of the pivot from the force.

The unit of moment of force is newton metre (N m).
In the above example, in the first case the perpendicular distance of the line of action of the force from the hinge is much more than that in the second case. Hence, in the second case to open the door, we have to apply greater force.

Fig. 1. Examples of nonacademic text (Lowrider, top) and academic text (TutorVista, bottom).

("Jason you are right on bro"). Though both the Lowrider authors are writing to inform, they are not assuming the impersonal authoritative voice that is characteristic of academic language. They claim their authority to provide information about the advantage of torque over horsepower adjustments on the basis of personal experience. The scientist's authoritative stance, on the other hand, derives from membership in a community committed to a shared epistemology; this stance is expressed through a reduction in the use of personal pronouns, a preference for epistemically warranted evaluations (such as "rigorous study" and "questionable analysis") over personally expressive evaluations (such as "great study" and "funky analysis"), and a focus on general rather than specific claims. Maintaining the impersonal authoritative stance creates a distanced tone that is often puzzling to adolescent readers and is extremely difficult for adolescents to emulate in writing.

Perhaps the simplest basis for comparing the Lowrider and TutorVista texts is to consider how rare in other contexts are the words they use most

frequently. The rarest words used in the Lowrider text are the special term "lolo" and its alternative form "lowrider," "upgrade," "carb," "HP," "exhaust," "spin," and "torque." Only two words from the Academic Word List (*10*), a list of words used frequently across academic texts of different disciplines, appear in this passage. The TutorVista text rare words include "magnitude," "perpendicular," "lever," "pivot," "hinge," "fulcrum," and "torque," and it uses the academic words "task," "maximum," "significance," and "illustration." The difference in word selection reflects the convention in the more academic text of presenting precise information in a dense, concise manner.

Nominalizations are a grammatical process of converting entire sentences (such as "Gutenberg invented the printing press") into phrases that can then be embedded in other sentences (such as "Gutenberg's invention of the printing press revolutionized the dissemination of information"). Nominalizations are crucial to the conciseness expected in academic language. In the TutorVista sentence "We may increase the turning effect of the force by changing the point of application of force and by changing the direction of force," "application" and "direction" are nominalizations representing entire propositions. "Application" is shorthand for "where we apply," and "direction" is shorthand for "how we direct." Thus, although this sentence has the same apparent structure as "We can get a smile from a baby by changing his diaper and by patting his back," the processing load is much higher. "Increase" in the original sentence is a verb referring to a relation between two quantities, whereas "get" in the baby-sentence adaptation refers to an action or effect in the real world. "Diaper" and "back" are physical entities subjected to actions, whereas "application" and "direction" are themselves actions that have been turned into nouns. Part of the complexity of academic language derives from the fact that we use the syntactic structures acquired for talking about agents and actions to talk about entities and relations, without recognizing the challenge that that transition poses to the reader. In particular, in science classes we may expect students to process these sentences without explicit instruction in their structure.

Science teachers are not generally well prepared to help their students penetrate the linguistic puzzles that science texts present. They of course recognize that teaching vocabulary is key, but typically focus on the science vocabulary (the bolded words in the text), often without recognizing that those bolded words are defined with general-purpose academic words that students also do not know. Consider the TutorVista definition of torque: "Torque is the product of the magnitude of the force and the lever arm of the force." Many 7th graders are unfamiliar with the terms "magnitude" and "lever"; and some proportion will think they understand "product," "force," and "arm" without realizing that those terms are being used in technical, academic ways here, with meanings quite different from those of daily life. Yet this definition, with its sophisticated and unfamiliar word meanings, is the basis for all the rest of the TutorVista exposition: the trade-off between magnitude and direction of force.

Efforts to help students understand science cannot ignore their need to understand the words used to write and talk about science: the all-purpose academic words as well as the discipline-specific ones. Of course some students acquire academic vocabulary on their own, if they read widely and if their comprehension skills are strong enough to support inferences about the meaning of unknown words (*11*). The fact that many adolescents prefer reading Web sites to books (*12*), however, somewhat decreases access to good models of academic language even for those interested in technical topics. Thus, they have few opportunities to learn the academic vocabulary that is crucial across their content-area learning. It is also possible to explicitly teach academic vocabulary to middle-school students. Word Generation is a middle-school program developed by the Strategic Education Research Partnership that embeds all-purpose academic words in interesting topics and provides activities for use in math, science, and social studies as well as English language arts classes in which the target words are used (see the Web site for examples) (*13*). Among the academic words taught in Word Generation are those used to make, assess, and defend claims, such as "data," "hypothesis," "affirm," "convince," "disprove," and "interpret." We designed Word Generation to focus on dilemmas, because these promote discussion and debate and provide motivating contexts for students and teachers to use the target words. For example, one week is devoted to the topic of whether junk food should be banned from schools, and another to whether physician-assisted suicide should be legal. Discussion is in itself a key contributor to science learning (*14*) and to reading comprehension (*15*, *16*). Words learned through explicit teaching are unlikely to be retained if they are taught in lists rather than embedded in meaningful texts and if opportunities to use them in discussion, debate, and writing are not provided.

It is unrealistic to expect all middle- or high-school students to become proficient producers of academic language. Many graduate students still struggle to manage the authoritative stance, and the self-presentation as an expert that justifies it, in their writing. And it is important to note that not all features associated with the academic writing style (such as the use of passive voice, impenetrability of prose constructions, and indifference to literary niceties) are desirable. But the central features of academic language—grammatical embeddings, sophisticated and abstract vocabulary, precision of word choice, and use of nominalizations to refer to complex processes—reflect the need to present complicated ideas in efficient ways. Students must be able to read texts that use these features if they are to become independent learners of science or social studies. They must have access to the all-purpose academic vocabulary that is used to talk about knowledge and that they will need to use in making their own arguments and evaluating others' arguments. Mechanisms for teaching those words and the ways that scientists use them should be a part of the science curriculum. Collaborations between designers of science curricula and literacy scholars are needed to develop and evaluate methods for helping students master the language of science at the undergraduate and high-school levels as well as at the middle-school level that Word Generation is currently serving.

References and Notes

1. Carnegie Council on Advancing Adolescent Literacy, *Time to Act: An Agenda for Advancing Adolescent Literacy for College and Career Success* (Carnegie Corporation of New York, New York, 2010); http://carnegie.org/fileadmin/Media/Publications/PDF/tta_Main.pdf.
2. J. Johnson, L. Martin-Hansen, *Sci. Scope* **28**, 12 (2005).
3. M. A. K. Halliday, paper presented at the Annual International Language in Education Conference, Hong Kong, December 1993.
4. M. J. Schleppegrell, *Linguist. Educ.* **12**, 431 (2001).
5. M. A. K. Halliday, J. R. Martin, *Writing Science*: *Literacy and Discursive Power* (Univ. of Pittsburgh Press, Pittsburgh, PA, 1993).
6. A. Bailey, *The Language Demands of School: Putting Academic English to the Test* (Yale Univ. Press, New Haven, CT, 2007).
7. R. Scarcella, *Academic English: A Conceptual Framework* (Technical Report 2003-1, Univ. of California Linguistic Minority Research Institute, Irvine, CA, 2003).
8. C. Snow, P. Uccelli, in *The Cambridge Handbook of Literacy*, D. Olson, N. Torrance, Eds. (Cambridge Univ. Press, New York, 2008), pp. 112–133.
9. Z. Fang, *Int. J. Sci. Educ.* **28**, 491 (2006).
10. A. Coxhead, *TESOL Q.* **34**, 213 (2000).
11. J. Lawrence, *Read. Psychol.* **30**, 445 (2009).
12. E. B. Moje, M. Overby, N. Tysvaer, K. Morris, *Harv. Educ. Rev.* **78**, 107 (2008).
13. C. Snow, J. Lawrence, C. White, *J. Res. Educ. Effectiveness* **2**, 325 (2009); www.wordgeneration.org.
14. J. Osborne, *Science* **328**, 463 (2010).
15. J. Lawrence, C. Snow, in *Handbook of Reading Research IV*, P. D. Pearson, M. Kamil., E. Moje, P. Afflerbach, Eds. (Routledge Education, London, 2010).
16. P. K. Murphy, I. A. G. Wilkinson, A. O. Soter, M. N. Hennessey, J. F. Alexander, *J. Educ. Psychol.* **62**, 387 (2009).

17. Preparation of this paper was made possible by collaborations supported by the Strategic Education Research Partnership and research funded by the Spencer Foundation, the William and Flora Hewlett Foundation, the Carnegie Corporation of New York, and the Institute for Education Sciences through the Council of Great City Schools. Thanks also to www.TutorVista.com for permission to reprint their lesson on torque.

10.1126/science.1182597